HAYS (B.F.)

THE

LIFE WORK

OF

CARL WILHELM SCHEELE.

A Paper read before the Alumni Association of the College of Pharmacy of the City of New York.

BY

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THE LIFE-WORK OF CARL WILHELM SCHEELE, THE SWEDISH APOTHECARY.*

By Benjamin Frank Hays, Ph.G.

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It affords me a great deal of pleasure to call your attention to the life and work of a man who, while he achieved the greatest fame as a chemist, never deserted his calling, and remained an

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no inclination for a study of the higher literary branches, his inquiring mind being naturally attracted by a love of investigation towards chemistry, and as a means of gratifying this desire we find him at the age of fifteen engaged as an apprentice to the apothecary of Gothenburg.

Let us stop for a moment and inquire into the causes which conspired to lead the apprentice on to those wonderful discoveries upon which his fame shall evermore rest. Like a true child of genius, we find him here viewing the occurrences that transpire in a pharmacist's busy life with open eyes and mind filled with wonder, and it is in these very points that genius gives proof of its genuineness. While the majority of mankind accept facts

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without endeavoring to substantiate them, and come to regard every-day occurrences as commonplace, genius, like a little child asks for the "why," and views the things men call ordinary with amazement bordering upon awe. The great difference between men of genius and ordinary mortals lies in the fact that the latter need sign-posts and lanterns to direct their footsteps, while the former have little use for such aids, and become, as it were, sign-posts and lanterns themselves to the rest of humanity. While millions of people shuddered at the sound of the thunder and hid themselves in dark rooms from fear of the lightning, Franklin went out into the storm and drew electricity from the clouds.

That Scheele was a genius, there is no room for doubt. Perhaps some simple accident in the laboratory first kindled Scheele's enthusiasm, and his ardor once kindled, burned with an unquenchable flame, and in order to satisfy this craving for knowledge, having no special time to devote to his favorite pursuit, we find him depriving himself of much needed rest; but to him this was no sacrifice, for herein lay his whole source of amusement and recreation. Nature is inexorable; she gives nothing for nothing; she hides her secrets in her bosom, and every fact man wrenches from her is by payment of just so much labor or life. As Longfellow says:

> "The heights by great men reached and kept,
> Were not attained by sudden flight;
> But they, while their companions slept,
> Were toiling upwards in the night."

While Scheele's comrades were carousing, he was experimenting, and with the lighted lamp of science in his hand mounted the tower of knowledge and engraved his name indelibly upon every step. Of the early details of Scheele's life very little is known. After serving his apprenticeship at Gothenburg he remained at that city for a number of years, and while here studied the works of the standard authors of the day, among whom we may mention Lemery, Kunkel, Neumann, and Stahl, and the latter's writings seem to have exerted a great influence over him, as indeed they did throughout the whole civilized world. After leaving Gothenburg, Scheele went to Malmo, and from there to Stockholm, and in 1773 settled at Upsala. During these years he filled the position of assistant in various pharmacies.

But while his feet wandered from place to place, his love for chemistry never wavered, and it is largely due to the experiments and investigations that he conducted during this time that a way was opened to those brilliant discoveries that later in life placed him by the side of the ablest men of the day.

At Upsala he received a position in a pharmacy, and while here, through a trifling occurrence, became acquainted with the Swedish chemist Bergmann, who then occupied the chair of chemistry at the University. One day the proprietor of the pharmacy in which Scheele was engaged noticed that when saltpetre was heated to a moderate degree it melted, and that if the temperature was raised a copious supply of gas was given off; then when the salt became cold, if acetic acid was added, red vapors were disengaged. He was ignorant of the cause of the reaction, and being acquainted with Gahn, who was then studying at the university, and who afterwards became a chemist of note, went to him to seek an explanation; but Gahn knew no more of it than his friend, and he in turn sought Bergmann, who, as an example of the knowledge that then existed among chemists, was compelled to admit that he did not know the cause, when Scheele, accidentally overhearing the conversation, ventured to give an intelligent explanation, and this came to the ears of Bergmann, who expressed a desire to see Scheele, and thus began an acquaintance that lasted through life. Even at this early date Scheele began to develop the characteristic qualities of an experimenter: he was one of the first to make actual investigation take the place of speculation, one of the first to intelligently use reagents, and with this knowledge was enabled to tell a new body when he came in contact with it; following up every reaction until he obtained the whole truth, he carefully examined every step of ground he went over, and allowed nothing to escape him, one discovery leading on to others.

His earliest researches, of which I find any account, were made in the domain of organic chemistry, and in these investigations he had no predecessor; and when we consider the strides he made in this intricate department of science, we begin to form some idea of his genius.

He was attracted to this study by observing that the juices of various plants and fruits were acid, and he endeavored to discover what acid they contained. Now tartar, the deposit from

grape-juice, was known to consist of an acid and an alkaline base, but Scheele was the first to isolate this acid, which he obtained in the crystalline state. He accurately studied and described its properties, recognized it to be a new compound, which, on account of its origin, he called Tartaric Acid.

In unripe apples he discovered malic acid, and was the first to point out the difference between citric and tartaric acids, and to obtain citric acid in a pure state.

Various other plants were known to contain saline bodies, but these were supposed to be one or other form of the combination of mineral acid with alkalies, and the salt that was present in rhubarb root was thought to be a sulphate of potash, until Scheele proved it to be an oxalate of lime, and found that many other plants contained it, and published a list of thirty-seven different plants in which he detected this acid combined with either lime or potash.

His mode of ascertaining the presence of oxalate of lime was to macerate the drug reduced to powder in muriatic acid, then to filter the solution and add ammonia in excess, when if oxalate of lime was present he obtained a white precipitate. Continuing his experiments, he isolated oxalic acid, and later while experimenting upon sugar found that he obtained from that body by action of nitric acid a new substance, which he proved to be oxalic acid, and identical in composition with that which he obtained from the various plants.

When a few years ago Kolbe discovered that he could synthetically make salicylic acid, the world hailed the discovery with a glad shout; but poor Scheele's discovery that oxalic acid could be made in the laboratory, although equal in importance to the German chemist's work, aroused very little enthusiasm.

His plan for the separation of the organic acids was to saturate the juice of the plant with chalk, and to decompose the resultant lime salt of the unknown acid with either muriatic or sulphuric acids. When the organic acid was soluble in water, he used sulphuric acid, thereby setting the acid free in solution, and producing an insoluble salt of lime, which was filtered off, and the acid solution set aside to crystallize.

When the acid was insoluble in water, as in the case of benzoic acid, he decomposed the lime salt with muriatic acid, and in this

way forming a very soluble salt of lime, and setting the acid free as a precipitate, which was separated by filtration.

Scheele was the first to introduce this method, which equals our most approved methods to-day, for previous to that time the only way of preparing these acids, of which only a very few were known, was by sublimation.

In endeavoring to discover the causes which led to the souring of milk, he discovered lactic acid, and gave a method for its production upon the large scale, and while engaged upon this investigation found that he could prepare oxalic acid by action of nitric acid on milk sugar.

He was the first to chemically examine the urine, and to discover uric acid, which he proved was always present; and also pointed out the presence of benzoic acid in urine, and gave a method for the preparation of the same.

Phosphorus was first discovered by Brandt, who detected its presence in urine while endeavoring to extract from that liquid a substance capable of transmuting silver into gold; and Dr. Gahn first pointed out that there existed in bones combined with lime an acid similar to that occurring in urine, and Scheele soon after proved this salt to be phosphate of lime, and gave a method for the extraction of the phosphorus.

Here, as elsewhere, Scheele figures as the practical chemist, who not only made discoveries, but put them to actual use; yet much of the honor that should be his is given to others: he suffered as scientific and literary men do to-day at the hands of pirates.

While Scheele was at Stockholm he sent to the Academy an elaborate account of his investigation of tartaric acid; but no notice was taken of it, and, impatient of the delay, he rewrote the article, and gave it into the hands of Retzius, the clerk of the college, and in 1770 the paper was published in the Transactions of the Stockholm Academy, but in such a way that the whole credit was given to this Retzius. But Nature takes care of her children's honor, and posterity crowns many a man whose life was blighted by just such causes.

Two of Scheele's important investigations in organic chemistry were in connection with glycerine, and Prussian, or Berlin blue, as it was then called.

Perhaps you think I lay too much importance upon such sim-

ples; but you must remember that Scheele possessed no such advantages as the student of chemistry does to-day. An humble apothecary's clerk, working with poor apparatus, he has set an example that should stimulate all young men to attempt to follow where he led.

Glycerine was discovered by Scheele while heating oxide of lead with olive-oil in the preparation of lead-plaster. He recognized it to be a new body, closely studied its properties, found it could be obtained from various other oils and fatty bodies, and called it the "Sweet Principle of Fats." This discovery, the real value of which Scheele never fully recognized, must be considered as one of his most important when we think to what an extent the manufacture of glycerine has grown.

His experiments with Prussian blue show his ability as a chemist, and illustrate one of the most interesting events of his life. Prussian blue was discovered by an accident about the year 1710. Dresbach, a manufacturer of colors in Berlin, wished to prepare a red lake, and borrowed from the chemist Dippel, who was the discoverer of a peculiar oil which he obtained by the destructive distillation of animal matter, and which is known as "Dippel's Oil" to-day, some alkali that the chemist used in the preparation of this oil, and when Dresbach added the alkali to his mixture of cochineal, alum, and green vitriol, he obtained a blue instead of the red color he sought. He mentioned this fact to Dippel, who soon succeeded in preparing this pigment at will, and which acquired a large sale under the name of Prussian blue. Dippel did not know the origin of this color, and though various chemists endeavored to explain it, its manufacture remained a secret until 1724, when Dr. Woodward published a formula for making it, and the celebrated chemist Macquer began an investigation to discover the source of the color, and after an elaborate series of experiments came to the following singular conclusion: "Prussian blue is nothing more than iron supersaturated with phlogiston." Now this body, phlogiston, with which we shall have soon to deal, seems to have played the part with the early chemists that malaria now does with the doctors: any fact a chemist could not explain was smoothed over by ascribing it to phlogiston—very much as many physicians nowadays cover up their defects of knowledge by classing whatever they cannot explain as malaria.

Scheele was the first to give a true explanation, which was published in the Transactions of the Stockholm Academy for 1782 and 1783. He observed that Prussian alkali after its exposure to the air lost its power of producing Prussian blue, and in order to discover what had become of it, placed a piece in a tightly-corked glass globe and allowed it to remain for several days, when upon testing it he found that no change had occurred. Accordingly he conceived the idea that something present in the air caused the decomposition, and came to the conclusion that it was the fixed air (CO_2). To determine this, he filled a globe with this gas, and placed a small piece of the alkali at the bottom, and allowed it to remain closed for twenty-four hours. Upon examining the salt at the end of that time he found it had lost its property as before. He repeated this experiment, but attached to the cork a slip of paper, which had been first dipped in a solution of sulphate of iron and afterwards in an alkaline solution to precipitate the iron. At the end of two hours he took out the cork, and moistened the slip with a drop of muriatic acid, and to his delight obtained a fine blue color. A modification of this test, known to-day as Scheele's test, is one of the most decisive we have for detecting hydrocyanic acid. Scheele next found that other acids would separate the coloring principle, as he then called it; and not satisfied with this knowledge, he determined to discover its composition, and for this purpose boiled Prussian blue with oxide of mercury and water until the blue color disappeared; then he filtered the solution, and added some iron filings and sulphuric acid, when the iron was completely dissolved and the mercury precipitated. To this solution consisting of the coloring principle and sulphate of iron he added some more sulphuric acid, and subjected the whole mixture to distillation, and obtained the coloring principle, as a thin, strongly smelling liquid, with the nature of which he was still unacquainted, which to further purify he redistilled over carbonate of lime. Still in the dark as to its origin, he sought further to find out its composition. To accomplish this he mixed some charcoal and potash in a crucible and kept the mixture at a red heat for some time; then he added a small quantity of sal-ammoniac, and continued the heat until all odor of ammonia was gone; when cold he dissolved the salt in water and obtained all the reactions of prussic acid, and from this concluded that it was a mixture of charcoal and ammonia.

but from want of proper apparatus could not tell what proportions, and it remained for Berthollet to prove that, while it contained the same elements as charcoal and ammonia,—that is, carbon, nitrogen, and hydrogen,—they occurred in different proportions, and he showed the formula to be HCN. This example, which I have given at length to show how much Scheele was in advance of his time, exhibits his power of research in a striking degree, and calls forth both admiration and wonder. While Scheele's fame rests upon his many discoveries, it will be necessary, in order to more properly appreciate his work, to glance at the theories that existed prior to and during his day. Chemistry did not begin to assume its position as a science until the time of Becher, about the middle of the seventeenth century; and it is only with the researches of Lavoisier, whose way Scheele prepared, that chemistry emerged from the mystery that had shrouded it. Prior to Becher, chemistry was in the hands of the alchemists, a body of men who, seeking rather to deceive than to instruct, endeavored to give the impression that they conversed with spirits, from whom they had learned the secret of how to indefinitely prolong life, and the power of transmuting all baser metals into gold. With the advent of more scientific methods the power of the alchemists dwindled away. Becher was the first to outline a theory of combustion, which was afterwards developed by his disciple Stahl into the Phlogiston theory, which was universally accepted by scientific men throughout the world until it was finally overthrown by Lavoisier. To show how firmly this theory had taken root, I quote from a chemistry published in London in 1788,* two years after Scheele's death, the following statement: "A modern sect of French philosophers, called Antiphlogistians, have endeavored to blow up this firs pillar of chemical theory; but in vain: it stands upon the firm basis of demonstration, and it will stand forever." In this same volume the four physical elements are described with their appropriate symbols as fire, air, earth, water, yet the preface contains this remarkable statement: "From the preceding part of this preface it must appear that chemistry is an entire new science; that all old books are useless, and that many of those of no very ancient date must be defective and erroneous."

* First Lines of the Theory and Practice of Philosophical Chemistry. By John Berkenhout, M.D. London, 1788.

In the year 1767 a series of experiments were instituted at the Paris Academy in order to prove that the elements were interchangeable, and more particularly that water could be converted into earth. You all no doubt remember the old story of how the earth that collected in the retort after repeated distillation was deemed conclusive evidence, until Scheele analyzed the deposit, and found it to consist of the same elements as the glass, and suggested that it might be derived from that source; and Lavoisier, following his footsteps, with the aid of the balance proved that while the water did not change, the retort lost in weight, and the loss just equalled the amount of the deposit. Thus this theory was overthrown.

Scheele did not believe that because two pieces of ore were obtained in the same locality that they must of necessity have the same composition.

Fire in olden times was regarded as a certain elementary body capable of devouring all combustibles and converting them into itself. They said, if you bring a small quantity of this substance —fire—to a grate full of charcoal or other combustible it imm ately begins to devour it, and whatever part is unfit for food is left behind in the form of ashes.

Becher's theory of combustion explained that process by stating that all metals were composed of an earthy substance common to all, and a combustible principle also common to all, while they differed from one another by a peculiar mercurial element; and that when a metal was heated so that it changed its form, the mercurial and combustible elements left it, and nothing remained but metallic calx.

Stahl's theory, which is simply an enlargement of Becher's, taught that all combustibles contained a combustible principle known as phlogiston, to which their combustibility was due. This principle was the same in all bodies, which differed from one another on account of other substances which they contained. Combustion depended upon this substance, and when it left a body, the remainder was incombustible.

Mayow pointed out that metals when calcined increased in weight; and the followers of the phlogiston theory endeavored to explain this fact by stating that as phlogiston is in itself the cause of gravity, it would be absurd to suppose that it possessed that property, but rather to be endowed with the power of levity; and

hence when phlogiston leaves a body it is not buoyed up as much as before, and consequently heavier. These ideas, crude as they seem, were a great stride towards the founding of a system by which events might be systematically studied.

In other sciences thought was not much further advanced. Linnæus, the great botanist, a countryman and contemporary of Scheele, in his "System of Nature," after outlining the formation of the earth, describes the ocean as follows:

"The water of the ocean, frigid, passive, concipient, everywhere fecundated a dry, calescent, active generating air, is observed teeming with a double offspring—a saline male, soluble, acrid, clear, and crystalline; a terrene female, fixed, viscid, opaque, attractorial;" and describes the following substances as occurring in sea-water:

"Muria, which is marine, and which by corrosion attracts clay; Natrum, which is animal, and which by refridation coagulates calx; Nitre, which is aerial, and which by obduction augments sand; Alum, which is vegetable, and which by ramification cements soil." "These are the fathers of the stones."

Again he describes four kinds of earth: "Clay, the earth of marine water; sand, the earth of rain-water; soil, the earth of vegetables; calx, the earth of animals;" and adds, "These are the mothers of the stones."

Now as Scheele lived in the latter part of the eighteenth century, during a time when the phlogiston theory was the accepted explanation of a great many phenomena, much of his writings bear the mark of this relic of ignorance, and shows to what straits chemists were reduced in order to make facts agree with this, as it seems to us now, ridiculous theory; and this brings us to Scheele's most important discovery—that of oxygen, the honor of which he shares with Priestley; and although there seems to be some doubt as regards dates, yet, as Lowell says, "Biography now holds dates cheaper and facts dearer" than it formerly did; and although, as I say, there seems to be some doubt as regards the dates, yet the fact that each discovered oxygen independently of the other is beyond question, Priestley calling it "dephlogisticated air," and Scheele "empyreal air," each working with different substances. Priestley obtained his gas while heating red precipitate, and Scheele his by the same method from black oxide of manganese.

It will be interesting to state here, that about one hundred years before this discovery, Dr. Hooke pointed out that there existed in air a certain body similar if not identical to that contained in saltpetre, though he says there exists in saltpetre a much larger quantity than is contained in a given bulk of air. This body possesses the property of dissolving all combustibles, but only when the temperature is considerably raised; and Mayow ten years later advanced this same opinion without giving Dr. Hooke any credit, and called this body "spiritus nitro-aereus."

In a treatise upon air and fire, contributed to the Stockholm Academy, Scheele, after a vast number of experiments, conducted with great skill, proved that the atmosphere was composed of two elastic fluids: one of these he called "fire-air and the other "vitiated air." He proved their presence in many ways: one method was to absorb out the fire air: this he did by means of a solution of liver of sulphur, or a mixture of iron filings and sulphur moistened with water. He found the relations of these gases always uniform, and recognized that fire-air was the same as the gas obtained from heating saltpetre, or from black oxide manganese.

This research is a masterpiece of work, but on account of the prevalent ideas he was led to wrong conclusions in regard to many of the phenomena. Had his life not been cut short at such an early age, he would, as was characteristic of him, have followed up his experiments until he obtained the truth. He was one of the first to doubt the phlogiston theory, but had no means of confirming his doubts. He says in this same essay, "I am disposed to believe that all acids owe their existence to fire-air"—an opinion, although erroneous, which was shared by Lavoisier. Through lack of proper apparatus he was not able to attach the importance to the combination of hydrogen and oxygen that it deserved. Scheele mixed H and O in a glass globe over water, and passed a spark through the mixture, when the gases united with a sharp report and the water rose until it completely filled the jar. Heat was generated, or, as it was called then, caloric, and as this was considered a property of phlogiston, Scheele thought that by union of H and O caloric was produced; and it remained for Cavendish to prove, by conducting this experiment in dry vessels, that not only was heat produced, but a second and more important result was

obtained, which led to the discovery of the composition of water. Scheele pointed out the power light possessed of decomposing certain salts, and showed that the violet ray was the most active and the red the least, but supposed that the difference was owing to different quantities of phlogiston with which the rays were combined, the violet containing the most and the red the least.

Another important investigation of Scheele's was in connection with manganese, and while engaged upon this body he discovered chlorine and barium, and in the latter body recognized a reagent for sulphuric acid. Mayow had endeavored to prove that phlogiston was identical with hydrogen, and Scheele accepted this view, and called the gas he obtained by action of muriatic acid on black oxide manganese "dephlogisticated muriatic acid." He studied its qualities, but found it contained no O; yet many chemists believed that it was a compound of O, and called it oxygen muriatic-acid, which was contracted afterwards by Kirwan to oxy-muriatic acid, and finally changed to chlorine by Sir H. Davy, who proved that it contained no O, and confirmed the ideas of Scheele.

He discovered a new element in fluor-spar, and was the first to make hydrofluoric acid, but was unable to obtain it pure, as it attacked the glass and dissolved the silica; and here again others with superior apparatus received the credit that should have been his. An anecdote in relation to alum will show how conversant he was with analytical methods. Baum supposed that when fluor-spar was melted with potash, and the mixture treated with sulphuric acid, that he could obtain alum. He accordingly mixed these two bodies, placed them in a crucible, and heated them, and after removing from the fire when the mixture had cooled, he treated the mass with sulphuric acid, and evaporated the solution, and obtained alum in crystals, which was deemed conclusive enough, until Scheele showed that the alum was derived from the crucible in which the experiment had been conducted. He discovered wolframic and molybdic acids, and proved the difference between molybdena and plumbago, with which it had previously been confounded. He discovered the nature of plumbago, by finding that it was entirely consumed when thrown upon melting saltpetre; he also first gave the hint that afterward led to the discovery of the composition of steel.

His experiments with arsenic, whereby he discovered arsenic

acid and arseniuretted hydrogen, are very interesting; but there is so much work that I can but briefly outline it. Arseniuretted hydrogen he discovered accidentally, yet with his accustomed ability followed up the discovery until he had learned all he could about it; he found that it was combustible, and deposited arsenicum when burnt. It is to this important discovery that the so-called Marsh's test, which should be called Scheele's test, depends. He was not only aware that he could generate the gas from metal and an acid to which he had added some arsenic, but also that all metals contaminated with arsenic gave the same results.

He contributed very much to the knowledge of ether, and made a great many organic ethers, which have no other value than to illustrate the range of his experiments, among which the may be mentioned, oxalic, citric, tartaric, and benzoic ether. He also proposed the method for making acetic ether which is in use to-day.

He proved the similarity between calomel prepared by sublimatum and that by precipitation, and was one of the first to early study and describe the properties of albumen.

Scheele lived a quiet, peaceful life, happy in his work, and to within a year of his death was simply an assistant. In 1775 he went from Upsala to Köpping, to take charge of a pharmacy, the proprietor of which had recently died; and here he seems to have conducted the business so well that he won the good graces of the widow, and married her two years later; here he remained until his death, which occurred in 1786.

When we look back at the amount of work Scheele contrived to do while attending to his regular duties, we ask ourselves with wonder how he found time for all this; yet he is but another example of the earnest worker, who, without education or means, but by perseverance and energy, "finds a way, or makes one."

This paper is offered as a tribute to the memory of a man who, while his name will always be connected with the most brilliant chemical discoveries, will also be known as the "Gothenburg Apothecary;" and the writer hopes that some one with more ability than he possesses will follow these footsteps, and show us more of this genius, and stimulate young pharmacists of to-day, by showing what may be done under obstacles. Poor, unaided, without station, Scheele won for himself a very dear place in the hearts of all men of science; and it is eminently proper that we

honor him now, inasmuch as he received so little during his life.

All the sciences owe much to pharmacy, and it in turn is deeply indebted to them; yet if every college where chemistry is taught would endow one free scholarship to any struggling pharmacist who chose to take advantage of the opportunity, it would be no more than is due to the memory of this Swedish apothecary, Carl Wilhelm Scheele.